Preliminary studies on integrating biocontrol methods with synthetic acaricides on red spider mite (*Oligonychus coffeae,* Nietner) infesting tea (*Camellia sinensis* L. (Kuntze)) in South India

Duraikannu Vasanthakumar[1], Manokaran Kamalakannan and Azariah Babu[2]

[1]*Upasi Tea Research Institute, Entomology Division, Tamil Nadu, India*
[2]*Tea Research Association, North Bengal Regional R & D Centre, Nagrakata Jalpaiguri District, West Bengal, India*

Corresponding author email: duraivasanthakumar@gmail.com

Tea plants (*Camellia sinensis* L. (Kuntze)) face various biotic stresses as a result of attacks from different pests. Among them, red spider mite (*Oligonychus coffeae,* Nietner) has been a major challenge in recent years in India. This study assessed the effectiveness of biocontrol methods along with judicious use of synthetic acaricides on red spider mite populations in tea gardens in South India. The results demonstrated the importance of integrating different modules of biocontrol procedures by using a natural enemy (*Mallada desjardinsi*) of the red spider mite, a bacterium (*Pseudomonas fluorescens*), aqueous leaf extracts of Indian wormwood (*Artemisia nilagirica*), along with judicious use of acaricides for effective population reduction. These results can be considered as a first step towards the utilization of various biocontrol methods in the management of red spider mite infestation in tea as they can be used to improve the existing management strategy for this pest.

Keywords: Red spider mites, *Mallada desjardinsi*, tea, *Artemisia nilagirica*, *Oligonychus coffeae, Camellia sinensis*

Red Spider Mite (RSM), *Oligonychus coffeae*, (Nietner) (Tetranychidae: Acarina) infestation has been a major challenge in cultivation of tea in India, causing 17%-46% crop loss (Muraleedharan et al. 2005). Dry weather conditions could favour the high incidence of mite infestation. *O. coffeae* infests the upper-surface of leaves, and, as a result of feeding on chlorophyll, the infested plants become defoliated, causing the death of bushes and losses in tea yield (Roy et al. 2014). Use of synthetic chemicals has been the control practice, over years, to overcome the crop loss due to red spider mite infestation. However, being an economically important export commodity, the production of tea has to be in compliance with international regulations with respect to pesticide residues. Different organizations such as the Environmental Protection Agency (EPA) of the USA, Codex Alimentarious Commission, Commission of European Communities (CEC) and Food and Agriculture Organization (FAO) have prescribed the maximum residue limits (MRL) of different pesticides on tea (Agnihothrudu and Muraleedharan 1990; Muraleedharan 1993, 1994).

Extensive and repeated use of synthetic chemicals over a long period of time could lead to undesirable effects such as contamination of the environment, destruction of natural enemies, development of resistance to pesticides and presence of undesirable residues in processed tea. These issues necessitate the development of alternative pest control strategies.

Integrated measures are suggested for the management of red spider mites in South India (Selvasundaram and Muraleedharan 2003). Insect parasitoids, predators and microorganisms play a vital role in the natural regulation of many tea pests. The minor status of many tea pests is obviously due to the influence of biological control agents (Muraleedharan and Selvasundaram 1995; Roy et al. 2010a). Botanical preparations also

play an important role in the management of pests in organic tea gardens. As of now, there are no documented efforts made to formulate effective pest management strategies for RSM in tea plantations of South India. Hence the present study was conducted to assess the effectiveness of biocontrol methods along with judicious use of synthetic acaricides on red spider mite populations in tea gardens in South India.

Materials and methods

Microplot experiments were carried out for two seasons (November-Season I and April-Season-II) to assess the effectiveness of biocontrol methods along with judicious use of synthetic acaricides in UPASI Tea Experimental Farm (N 10.2658°; E 76.9660°) South India, for the control of red spider mites. The non-chemical control methods have been chosen for this study based on the earlier reports (Vasanthakumar and Babu 2013; Rahman et al. 2013; Roobakkumar et al. 2011; Babu et al. 2010). Experimental plots (non-replicated) consisted of 900 bushes and were further divided into three plots of 300 bushes, each representing Experimental Plot I, Experimental Plot II and Experimental Plot III (water-treated control). In Experimental Plot I, propargite 57 EC @ 500 mL/ha, powder formulation of *Pseudomonas fluorescens* @ 1.5 kg/ha, aqueous leaf extracts of Indian wormwood, *Artemisia nilagirica* @ 5.0% concentration and egg cards of *Mallada desjardinsi* (natural enemy of RSM) @ 400/release were applied. Synthetic acaricides such as Propargite 57 EC (0.57 g a.i./ml) @ 500 mL/ha and Fenpyroximate 5 EC (0.05 g a.i./ml)@ 300 ml/ha were applied in Experimental Plot II.

Pretreatment assessment was carried out by collecting 75 leaves at random from each plot and counting the number of mites present on the leaves (Roy et al. 2010b). The first round of spraying was carried out one day after pretreatment assessment with Propargite 57 EC at 500 mL/ha in both the plots (Experimental Plot 1 and Experimental Plot II) by using a hand-operated knapsack sprayer with a spray volume of 450 L/ha. Water was sprayed as the control, Experimental Plot III. Based on the red spider mite population in Experimental Plots I and II, further rounds of spraying were done. The second round of spraying was carried out after 2 weeks by application of aqueous extracts of *A. nilagirica* in Experimental Plot I and Fenpyroximate in Experimental Plot II. The third round was done after the 5th week of observation by application of *P. fluorescens* in Experimental Plot I and Propargite in Experimental Plot II. After the 6th and 7th week of observation, eggs of *M. desjardinsi* were released in Experimental Plot I. Observations were carried out at weekly intervals. Data were subjected to ANOVA and means were separated by Tukey's test (SPSS, 17).

Results and discussion

Results of the experiments on the effectiveness of biocontrol methods along with judicious use of synthetic acaricides are presented in Table 1. The observation on the number of red spider mites clearly showed that the population of red spider mite/leaf was reduced in Plot I from 6.12 to 0.91 (Season I) and from 6.74 to 1.06 (Season II). In Plot II, the population of red spider mite/leaf was reduced from 5.87 to 0.81 (Season I) and from 6.49 to 0.91(Season II). This clearly indicated that in both plots, considerable reduction of red spider mite population was achieved. However, the intensity of synthetic pesticide usage was more (3 rounds) in Experimental Plot II than in Experimental Plot I (1 round).

Planters in the tea growing areas of South India are forced to spray a minimum of two to three rounds of synthetic acaricides like Propargite, Fenpyroximate, Hexythiazox, etc., during the red spider mite season. However, red spider mites have already become less susceptible to specific groups of acaricides as a result of continuous application over a long

period of time. This effect is compounded by the issues of carryover of pesticide residues in the tea product. The preferred way to tackle this situation is to integrate different modules of bio-control procedures along with judicious use of acaricides. The successful use of different biocontrol modules such as predators, microorganisms and plant products against different pests has been reported by several authors (Perumalsamy et al. 2009, 2010; Rahman et al. 2012; 2013; Subramaniam et al. 2010; Babu et al. 2008; Prabhakaran et al. 2017). Generally, none of the synthetic acaricides offer 100% reduction of red spider mite populations under field conditions. When practising integrated strategies, more effective control is possible. For example, release of *M. desjardinsi* in the tea field is one of the suggested integrated approaches to control red spider mite populations. After the application of synthetic acaricides, field released populations of *M. desjardinsi* will be more effective to kill the surviving red spider mites that have escaped from acaricides and those hiding in the places where acaricides coverage is poor.

Table 1: Effectiveness of biocontrol methods along with judicious use of synthetic acaricides against red spider mite

Treatments (Season I)	**Number of red spider mite/leaf (Mean ± SE)**								
	PT*	**I Week**	**II Week****	**III Week**	**IV Week**	**V Week*****	**VI Week#**	**VII Week##**	**VIII Week**
Propargite @ 500 mL/ha; *A. nilagirica* @ 5% *P. fluorescens* @ 1.5 kg/ha *M. desjardinsi* @ 400 eggs/release (Experimental Plot I)	6.12 ± 1.06a	1.16 ± 0.33a	4.09 ± 0.89a	1.69 ± 0.50a	3.18 ± 0.78ab	4.78 ± 1.13a	2.50 ± 0.56a	1.64 ± 0.34a	0.91 ± 0.27a
Propargite @ 500 mL/ha; Fenpyroximate @ 300 mL/ha (Experimental Plot II)	5.87 ± 1.20a	0.97 ± 0.36a	4.02 ± 0.77a	1.06 ± 0.27a	1.70 ± 0.48a	4.03 ± 0.73a	0.98 ± 0.28a	0.70 ± 0.23a	0.81 ± 0.25a
Experimental Plot III	5.97 ± 1.59a	5.85 ± 1.36b	6.14 ± 1.27a	6.03 ± 1.26b	6.31 ± 1.39b	6.50 ± 1.41a	7.99± 1.44b	9.72± 1.42b	11.53± 1.87b
(Season II)									
Propargite @ 500 mL/ha; *A. nilagirica* @ 5% *P. fluorescens* @ 1.5 kg/ha *M. desjardinsi* @ 400 eggs/release (Experimental Plot I)	6.74 ± 1.25a	1.87 ± 0.50a	5.16 ± 0.98a	3.18 ± 0.80a	3.93 ± 0.78ab	4.90 ± 1.18a	2.50 ± 0.50a	1.64 ± 0.46a	1.06 ± 0.24a
Propargite @ 500 mL/ha; Fenpyroximate @ 300 mL/ha (Experimental Plot II)	6.49 ± 1.18a	1.67 ± 0.37a	4.89 ± 1.02a	1.71 ± 0.42a	2.99 ± 0.72a	4.09 ± 1.07a	1.69 ± 0.31a	1.13 ± 0.24a	0.91 ± 0.27a
Experimental Plot III	6.89 ± 1.57a	7.09 ± 1.46b	6.57 ±1.41a	6.79 ± 1.56b	6.92 ± 1.63b	7.03 ± 1.34a	8.43 ± 1.57b	10.07 ± 1.79b	12.63 ± 1.95b

Figures followed by the same alphabets in a vertical column are not significantly different at five per cent level according to Tukey's test. Details of treatments: PT– Pretreatment; * Propargite in plot I & II; ** Aqueous extracts of *A. nilagirica* in plot I &Fenpyroximate in plot II;****Pseudomonas fluorescens* in plot I &Propargite in plot II; # First release of *M. desjardinsi* (only in plot I); ## Second release of *M. desjardinsi* (only in plot I)

It is obvious from these findings that the integration of biocontrol measures such as use of *P. fluorescens*, release of the natural enemy, *M. desjardinsi*, and spraying of aqueous extracts of *A. nilagirica*, not only help in reducing the usage of synthetic acaricides but also minimizes the population of red spider mites. This study can be considered as a first step towards utilizing these biocontrol methods along with acaricides for the management of red spider mites in tea gardens. However, large-scale studies on the effectiveness of these biocontrol methods against red spider mites should be assessed before recommending these procedures in the pest management programme.

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